Implicit – Explicit - Implicit

An Investigation of a Ship Impact on an Off-Shore Installation

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Introduction

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Engineering Simulation Team

Impact, thermal, structural, CFD, seismic, fracture, fatigue and more

More than 25 years experience LS-DYNA

- Large items falling 2mm
- Small items falling large distances
- Metal, wood, concrete and plastics
- Nuclear regulatory work, BfS, BAM, France, Japan, USA and UK
- NAFEMS Analysis Management Working Group (Salzburg 2013)

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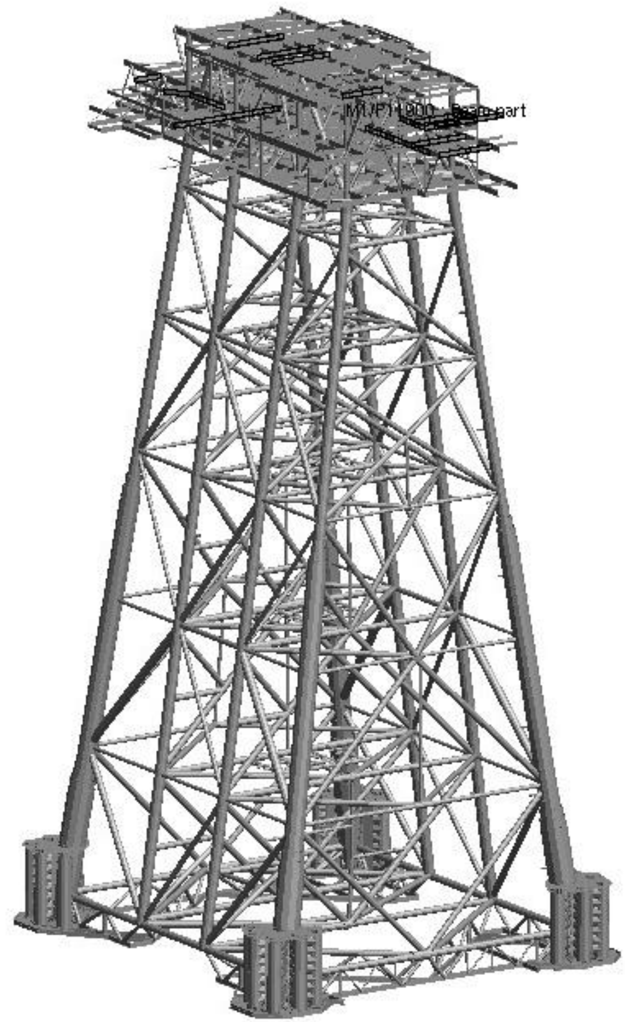
Description of the design problem

- Off-shore installation older than 25 years
- Increased workload
- Approaching end of life
- Extend life with additional installation
- Lack of space



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Description of the design problem

- No space on topsides
- Bracket connection below waterline not practical
- Mono-column approach selected
- Connected to existing piles
- Connected above waterline to topsides
- Truss isolated from mono-column via spherical bearings
- Vertical movement possible between truss and mono-column
- Wave loading imparts large forces to structure
- Gravity loading results in significant initial deflections
- Ship impact protection required because of limited redundancy compared to main platform
- Ship impact from various directions and at various height
- Entire structure must withstand 100yr storm loading after a potential ship impact
- Reserve safety factor required
- Existing approach is to consider removal of deformed section of the platform – DNV-SESAM, USFOS
- This cannot consider local energy absorption and local failure
- This is not applicable to structures with limited redundacy
- LS-DYNA explicit analysis required for detailed deformation modes

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Analysis requirement

- FE model of platform, truss, topside and mono-column exists in DNV-SESAM
- DNV-SESAM model mainly beam elements
- DNV-SESAM model, USFOS, contains loadings for gravity, appurtenances, wave loads, buoyancy, marine growth
- Detailed model of truss and mono-column required for impact analysis
- Translate DNV-SESAM to LS-DYNA, including beam sections and loadings
- Construct detailed FE model of truss and Mono-column in LS-DYNA
- Combine both models
- Perform initialisation analysis for gravity, buoyancy and 100 year return storm wave loading
- Confirm results from LS-DYNA match those from DNV-SESAM
- Perform impact analyses on pre-loaded model
- Perform stability analysis for 100 year return storm wave loading on deformed structure

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Analysis method

- Gravity and buoyancy loading
- Numerous impact analyses
- Post impact wave loading

- Use implicit throughout?
  - Would give incorrect impact performance

- Use explicit throughout?
  - Very time consuming
  - Too many load cases
- Convert DNV-SESAM model to LS-DYNA
- Create 3D shell and solid model of truss and mono-column
- Combine models for gravity and buoyancy loading
  - Need to ensure that loads from beams that are replicated in the 3D shell and solid model are transferred correctly and stiffness is not duplicated
  - Achieved by a “spider” of beams to link beam nodes to shell nodes
  - Duplicated beams given reduced stiffness and density or removed

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Analysis method - Implicit

- 1 beam replaced by approximately 1000 thin shell elements
- Beam loads translated to nodal loads
- Original beams removed
- Rigid body motions removed/restricted
    - Especially around bearing legs
- Implicit analysis completed for gravity and buoyancy (and 100yr wave)
- Reaction forces compared with DNV-SESAM results
- Ove Arup software OASYS used to generate initial stresses and strains from implicit analysis as starting point for explicit analyses

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Analysis method - Explicit

- Remove the “spider” beams – they control the timestep
- Use *INITIAL_STRESS_ and *INITIAL_STRAIN_ cards
- Free any restrained rigid body motions
- Position the ship for impact
- Complete the explicit analyses
  - A total of more than 50 impact cases was completed
  - Vital to have the pre-load stresses
  - Saving of more than 24 hours per analysis
  - Each analysis run for more than 2 seconds
  - Typically 4 days CPU on 8 processors for each analysis

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Analysis method - Implicit

- Deformed geometry, stresses and strain from impact analysis using Ove Arup OASYS software
- “Spider” beams added back in again for loading
- Model checked to ensure no free beams due to element deletion during impact analysis
- Implicit analyses completed for 19 load cases for each impact orientation

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Conclusions

- Use auto switching Implicit-explicit-implicit
  - Possible solution but would mean
    - Replication of initialisation
    - No automatic removal/replacement of “spider” beams
    - Problems if element deletion leads to “free” beams in implicit solution
- Use fully Implicit
  - Would not give correct impact deformation in such a large structure
- Use fully explicit
  - Load cases would take to long to solve without inducing dynamic effects
- Use manual switching Implicit-explicit-implicit
  - Logistically complex but proved to work
- Important to ensure that initialisation is correct
- Impact analysis must also include some “relaxation” time after the impact. Review the KE plots.
- Including damping in the explicit analysis can affect the initial loads and induce release of energy from the initial stresses
- Other problems identified in the transfer of the stresses in beams, dealt with in a separate presentation by Chris A Jones, AMEC